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COMPARATIVE EVALUATION OF PERFORMANCE AND EMISSION CHARACTERISTICS OF JATROPHA, PONGAMIA, MAHUA AND EUCALYPTUS OIL BASED BIODIESEL IN DIESEL ENGINE

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ABSTRACT

The rapid growth in population with their increasing energy requirement and increase in industrialization along with the continuous depletion of natural resources has forced us to search for an alternative fuel. These increases in demands have led to the exhaustive researches which gave more importance to study of biodiesel along with their properties. One of the important aspects of biodiesel is that it can be utilized in a diesel engine, devoid of any alteration in engine modification which made biodiesel as a promising alternative resource for future need. In this study, the best biodiesel blends were chosen and experiments were carried out in the conventional engine with no modification to analyze the performance characteristics along with combustion and emission parameters of biodiesel blend and related it with that of diesel properties. Here diesel was used as a reference fuel. Bio diesels were obtained from different oils such as Pongamia, mahua, jatropha and eucalyptus oil through the process of transesterification. The blend ratios taken for the test were B20. Further experiments were carried out to examine the properties of various biodiesel and its performance and emission characteristics with different blends ratio (J20, P20, M20, and E20) were studied and the results were weighed against properties of diesel. Among the various biodiesel blends, E20 proved to be a suitable biodiesel blend with an increase in brake thermal efficiency and the decrease in emission properties. Hence E20 proved to be a best alternate future fuel for diesel.

***KEYWORDS**: Trans-Esterification, Biodiesel, Brake Thermal Efficiency, Combustion & Emission Parameters*

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Original Article

INTRODUCTION

The increasing global need for energy and the depleting reserves *of* oil and gas led the researchers to search for an alternative fuel. Along with the need, the emerging concern over environmental pollution from industries and vehicles has resulted in the search for eco-friendly renewable fuel [1]. In order to sort out the fuel crises and environmental concerns, the research community suggested the usage of biodiesel as the suitable option for the regular fuel (diesel). The biodiesel also has the ability to reduce greenhouse gases. The other advantages of biodiesel are that it does not inhibit any strains of sulfur or rock oil dregs which resulted in improved combustion and emission characteristics [2]. It is attained from various traces such as vegetable oils, animal suet, algae etc.

A Switch from Diesel to Bio fuel

The latest researches proved vegetable oil as a promising alternative fuel for the future. The vegetable oil is not only replenishable but can also be easily cultivated on large scale without disturbing the ecological balance

[3]. Several analysis also showed that the capital cost required for the production of vegetable oil is also comparatively less than that of conventional sources. Till the date, nearly 400 oil-bearing crops are identified as promising alternative fuel for the synthesis of biodiesel [4]. These vegetable oils are further classified into edible oils such as palm oil, sunflower oil, soyabean oil etc., [5] and non-edible oil such as Pongamia, mahua, karanja etc., [6]. Direct usage of vegetable oil in engine causes problems such as poor fuel atomization, engine fouling, and incomplete combustion. The reasons for the above problems may be due to the high viscosity nature of vegetable oil. The high viscous nature of vegetable oil can be moderated through many process, one among such processes is transesterification. Through the process of transesterification the biodiesel is extracted from vegetable oil. The transesterification process is used in large-scale production of industrial biodiesel. Technically biodiesel is long-chain alkyl (methyl or ethyl) esters synthesized from vegetable oils or animal fat-based diesel fuel [7, 8]. Apart from its production and renewable property, it also has fewer emission characteristics than that of the conventional fuel [9]. It resulted in less production of hydrocarbon, carbon monoxide and smoke emission when weighed against characteristics of diesel [10]. One of the interesting fact about these biodiesels are it is feasible to use in the conventional engine with no modification in its parameters [11]. The latter researches proved biodiesel can be a practical expedient for diesel fuel. One of the main reason for considering it as a future fuel is in view of its oxygen content. The oxygen content in it resulted in reduced CO and HC emission which resulted in clean combustion. It is zero hazardous fuel and resulted in reduced sulfur content and zero soot formation. The biodiesel also has the greater flash point than diesel [12].

Biodiesel Blends with Diesel

The usage of biodiesel is advantages in terms of decrease in HC and CO emission but still, there is the rise in NO_X emission. The usage of these biodiesel blends proved more effective in the conventional engine with no engine modification than compared to that of regular biodiesel [13]. Further findings illustrated that the usage of biodiesel blends resulted in the decline in HC and CO emission [14, 15].

Thus the intension of this study is to analyze the diesel engine emission and performance characteristics using diesel and biodiesel fuel blends in the ratio as B20 for various biodiesel fuels. The biodiesel fuels procured for assessment are jatropha, mahua, Pongamia and eucalyptus oil biodiesel and the best blend was chosen for further analysis.

METHOD OF PREPARATION

In the present work, the analysis was performed on the SV1 model Kirloskar engine. It is water cooled four-stroke cycle, single acting, vertical single cylinder high-speed compression direct ignition engine with 661cc displacement and 17.5: 1 compression ratio. The fuel insertion pressure was 200 bar and the maximum brake power of the engine was developed 5.9 kW at 1800rpm. The lubrication system is a forced feed system. The engine was attached to an alternator along with a control system which measures and controls the speed and torque of the system. Figure 1 depicts the illustrative diagram of the investigation unit. The major factor taken into consideration are brake power, torque and specific fuel consumption of the engine. The eddy current dynamometer evaluates the brake power and torque. The eddy current dynamometer operates on the convention of eddy current. In order to detect the engine crank angle, the crank angle detector assembly (a crank angle marker and electromagnetic pickup) is used. Specific fuel consumption is defined as the mass flow rate of fuel consumed per unit power output. Using flow meter the Specific fuel consumption is evaluated. It is the fuel flow rate supplied to the engine. The time taken for 10cc of fuel consumption is regarded as fuel flow rate. It is

noted with the help of a stop clock. The output signal from the pressure transducer through a charge amplifier and Crank angle detector assembly was sent to signal conditioner. From the data acquisition system, the pressure of cylinder and crank angle graph, Heat release rate curve were obtained. The exhaust gas analyzer (EGA) is employed to determine exhaust gas emissions. It is done with the help of Crypton 290 series five gas emission analyzer. It takes transitory readings of exhaust gases liberated from the exhaust stream. It measures carbon monoxide and HC emission. A temperature of the exhaust gas was measured with Chromel Alumel (KType) thermocouples. The smoke opacity emission was evaluated through AVL brand smoke meter.

The fuels taken for investigations are diesel as reference fuel, jatropha oil, mahua oil, Pongamia oil and eucalyptus oil biodiesel. Further, the methodology of this investigation is divided into certain phases such as biodiesel preparation, blend preparation, and their characterization.

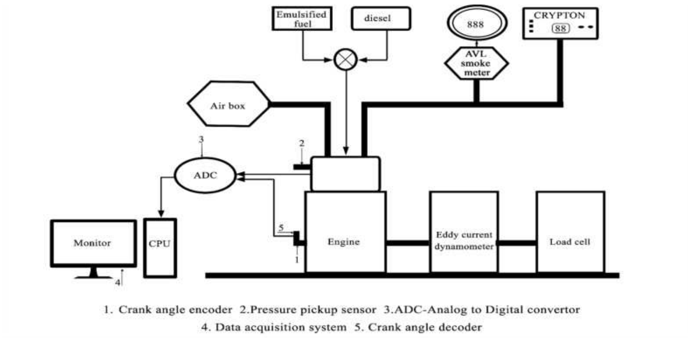

Figure 1: Schematic Diagram of the Experimental Setup

Production of Biodiesel

The most convenient way to prepare biodiesel was through the process of transesterification because it results in excellent productivity and gives good quality of fuel conversion [16]. In this method, the vegetable oil is treated with an alcohol either methanol or ethanol in companion of an acidic or basic catalyst to attain biodiesel. Technically the biodiesel is called as fatty acid esters and it yields glycerol as by-product. During the esterification process, the triglyceride is reacted with alcohol along with a catalyst, usually a strong alkaline like sodium hydroxide. The alcohol reverts a reaction on the fatty acids to form the mono-alkyl ester, or biodiesel and glycerol. The end of the trans-esterification reaction is denoted by the separation of the methyl ester (biodiesel) and glycerol in layers after the chemical process. The glycerol descends at the base of an experimental vessel which is a hefty co-product.

Biodiesel Blend Preparation

From the obtained biodiesel the biodiesel blend is prepared using diesel as base fuel. The biodiesel blend is prepared by mixing certain ratio of biodiesel with petroleum diesel in suitable ratio under appropriate circumstances. Here 20% jatropha oil and 80% diesel are represented as J20, 20% mahua oil and 80% diesel are represented as M20, 20% Pongamia oil and 80% diesel are represented as P20 and 20% eucalyptus oil and 80% diesel are represented as E20.

The 20% biodiesel and 80% diesel blends are chosen because it shows better emission and cold weather properties it also provides better material compatibility and fuel economy. The properties of diesel and various biodiesel are shown in table 1. The physical and chemical properties of the biodiesel blends are measured by standard test procedures and further the density, kinematic viscosity and flash points of the test fuel and biodiesel blends are determined and compared.

Table 1: Properties of Diesel and Various Biodiesel Fuel

Property	Diesel	Eucalyptus Oil	Jatropha Oil	Pongamia Oil	Mahua Oil
Kinematic viscosity at 40°c(cSt)	3.09	3.57	4.65	4.84	6.43
Calorific value (kJ/kg)	43198	42823	36694	3409	34597
Density at 15°C (kg/mm^3)	830	850	876	905	911
Flashpoint (°C)	56	70	85	87	91
Fire point (°C)	64	83	92	956	104

RESULT AND DISCUSSIONS

The performance and emission characteristics are analyzed for biodiesel blends and it is compared with properties of diesel. The following inference is drawn from the analysis:

Specific Energy Consumption

The specific energy consumption of different biodiesel was notably decreasing with brake power and engine speed. The specific energy consumption increases with biodiesel blend when compared with diesel. It was found to be 17.84%, 22.59%, 20.8% and 8.85% for J20, M20, P20 and E20 respectively. The high specific energy consumption is attributed to the low heating value of blends of biodiesel and minimal energy content when it was weighed against diesel [17]. Thus E20 diesel blend showed less specific fuel consumption when associated with other blends. Figure 2 depicts the specific energy consumption of fuels taken for this investigation.

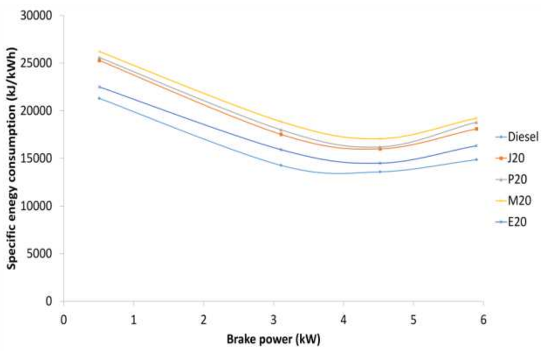

Figure 2: Brake Power Vs Specific Energy Consumption of Diesel and Various Biodiesel Blends (20% of Volume with Diesel)

Brake Thermal Efficiency

In comparison with diesel, the brake thermal efficiency of biodiesel blends was observed to decrease. The overall brake thermal efficiency of J20, P20, M20 and E20 calculated where 4.51%, 5.4%, 6.10% and 2.5%. Due to more viscosity and low calorific value of the biodiesel blend, the brake thermal efficiency was notably decreasing while compared with diesel [18]. The viscosity of E20 biodiesel was slightly lower which led to a trivial decrease in brake thermal efficiency when compared to diesel. Figure 3 depicts the brake thermal efficiency of different biodiesel blends and reference fuel.

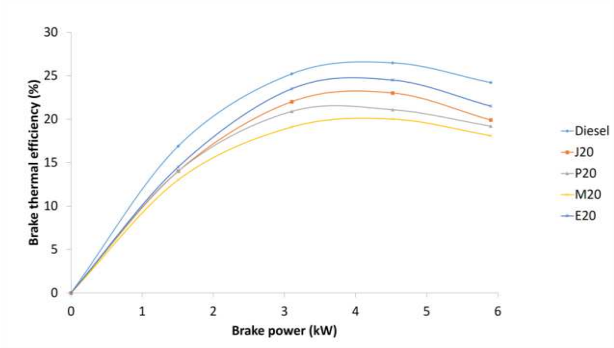

Figure 3: Brake Power Vs Brake Thermal Efficiency of Diesel and Various Biodiesel Blends (20% by Volume with Diesel)

Unburnt Hydrocarbon (HC) Emission

The less or non-availability of oxygen for effective combustion results in the emission of hydrocarbon. The hydrocarbon emission was found to decrease by 5.4045%, 4.04%, 2.700% and 6.754% with J20, P20, M20, and E20 while that of diesel was 74ppm at 100% load condition. Among all biodiesel blend E20 results in less HC emission than other biodiesel fuel. The reason is attributed to its increasing level of oxygen content than that of diesel [19]. Figure 4 depicts the HC emission of reference fuel and its biodiesel blends.

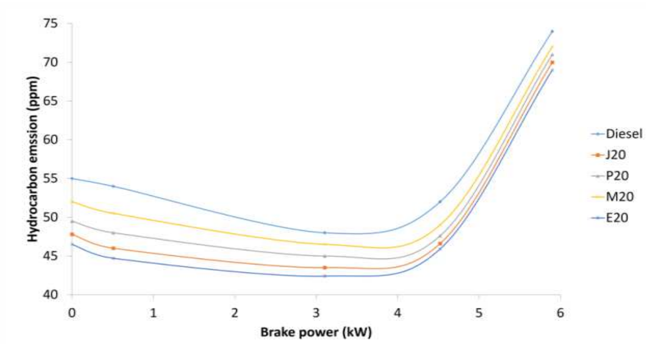

Figure 4: Brake Power Vs Hydrocarbon (HC) Emission of Diesel and Various Biodiesel Blends (20% of Volume with Diesel)

Carbon Monoxide (CO) Emission

From figure 5 it was found that the decrease in carbon monoxide emission is greater for E20 when compared to other biodiesel fuel and then that of reference fuel. The CO emission of E20 was found to decrease by 0.0121% whereas for other blends are 0.011%, 0.003% and 0.001% for J20, P20, and M20 respectively. The carbon monoxide emission is attributed to inadequate combustion of fuel [20].

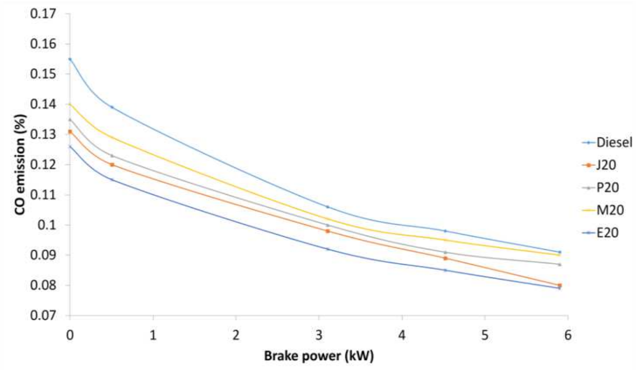

Figure 5: Brake Power Vs Carbon Monoxide (CO) Emission of Diesel and Various Biodiesel Blends (20% of Volume with Diesel)

Smoke Opacity Emission

From the analysis, it was noted that the smoke opacity emission was extreme for biodiesel blends when weighed against diesel. The smoke opacity of biodiesel blends was 5.7HSU, 6.69HSU, 7.71HSU and 3.9HSU for J20, P20, M20 and E20 respectively. The intensification of smoke opacity was attributed to excessive viscosity and minimal volatility which leads to slower combustion reaction [21]. While the smoke emission of E20 blend was comparatively similar to that of diesel. Figure 6 depicts the smoke opacity emission of various biodiesel blends and diesel fuel.

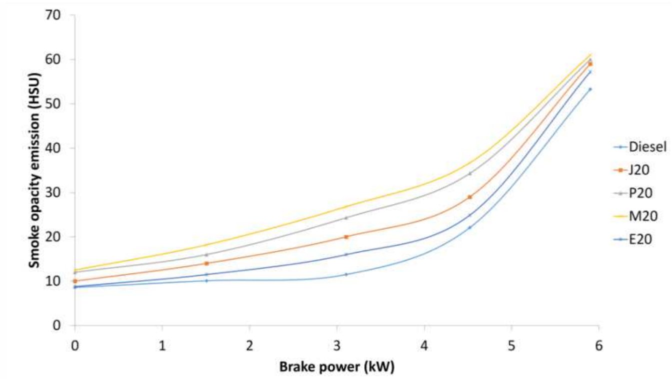

Figure 6: Brake Power Vs Smoke Opacity Emission of Diesel and Various Biodiesel Blends (20% of Volume with Diesel)

Oxides of Nitro gen (NO_X) Emission

Figure 7 depicts the NO_X emission of various biodiesel blends and diesel fuel. The NO_X emission was found to increase with an increase in biodiesel blend which was 13.872%, 77.66%, 3.512% and 2.194% for J20, P20, M20 and E20 respectively. The presence of oxygen and high-level cetane number resulted in enhanced NO_X emission for biodiesel blend [22]. Among the various biodiesel blends, the NO_X emission of E20 was similar to that of diesel.

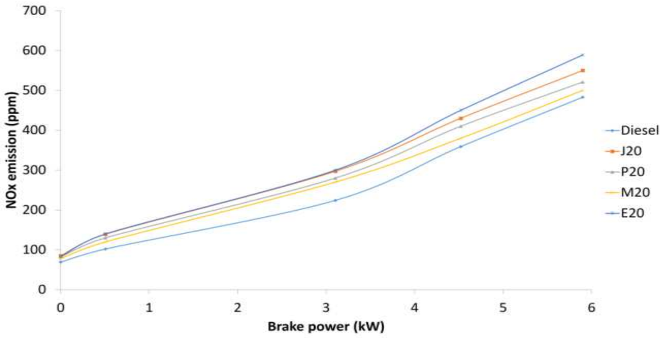

Figure 7: Brake Power Vs Oxides of Nitrogen (NO_X) Emission of Diesel and Various Biodiesel Blends (20% of Volume with Diesel)

Cylinder Pressure Vs Crank Angle Graph

Figure 8 shows the comparison of cylinder pressure for diesel, J20, P20, M20 and E20. The high point pressure of biodiesel blends was noted as being decreased by 7.57%, 8.44%, 11.265% and 2.810% for J20, P20, M20, and E20. The decrease in peak pressure might be attributed to higher calorific value and lower viscosity of biodiesel blends. The lower viscosity leads to better atomization as well as the enhanced mixing of air marks efficient incineration. The significant decrease in peak pressure was found with E20 biodiesel compared to other biodiesel blends.

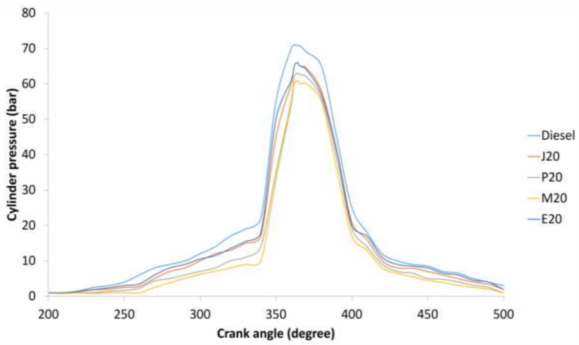

Figure 8: Cylinder Pressure Vs Crank Angle Graph of Diesel and Various Biodiesel Fuel

Heat Release Rate (HRR)

Figure 9 depicts the heat release rate of diesel and various biodiesel fuels blends. The high point heat release rate of biodiesel blends was found to be 83.51 J/degCA, 82.32 J/degCA, 84.43 J/degCA and 85.31 J/degCA for J20, P20, M20 and E20 respectively. The high point heat release was noted to be lowest with diesel by 81.2 J/degCA. The ignition delays of all biodiesel were noted as being more than that of reference fuel. It may be due to their less cetane value which resulted in more fuel accumulation leading to higher heat release than diesel. The heat release rate of E20 biodiesel was almost nearer to reference fuel.

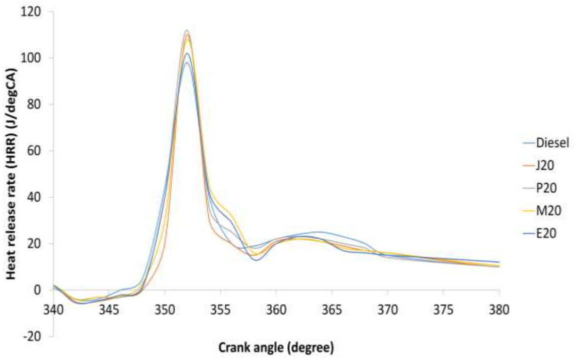

Figure 9: Heat Release Rate (HRR) Vs Crank Angle Graph of Diesel and Various Biodiesel Fuels

Exhaust Gas Temperature

Figure 10 shows the graph between brake power and exhaust gas temperature of diesel and other biodiesel blends. Exhaust temperature was found to be improving with raise in load for both reference fuel and other blends. The exhaust gas temperature of biodiesel blend was found to increase by 7.51%, 17.2%, 20% and 5.01% for J20, P20, M20, and E20 respectively. The raise in exhaust gas temperature was attributed to the continuous burning of dense molecules of biofuel. However, the E20 biodiesel showed similar in the emission of exhaust gas temperature as that of diesel.

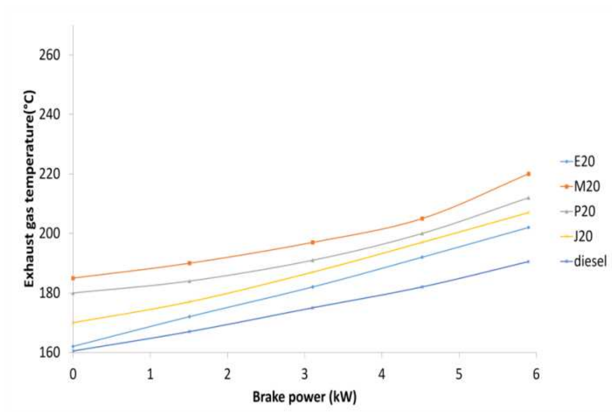

Figure 10: Brake Power Vs Exhaust Gas Temperature Graph of Diesel and Various Biodiesel Fuels

CONCLUSIONS

From the result and analysis of this study, it can be inferred that the diesel and biodiesel blend is more eco-friendly fuel than reference fuel (diesel) and can be availed as a substitute fuel for future. Among the various biodiesel blends E20 physical and chemical properties were marginally equal to diesel. The HC and CO emissions were also found to decrease by 6% and 0.012% for E20 when compared to other biodiesel blends and lower than that of diesel. The brake thermal efficiency was found to improve with E20 biodiesel. The performance and emission characteristics of E20 biodiesel were also comparable to diesel. It is also significant that the E20 biodiesel can be used in the diesel engine with no modification in engine parameters. Therefore the E20 diesel blend is the best option for diesel.

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